

Design of Blanking Die for Stiffening Rib: A Case Study

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ABSTRACT: Metal cutting is used for cutting a metal of particular shape and size from metal sheet. Metal cutting operations are widely performed on press machines. The two types of operations that are performed on press machines are shearing and forming operations. These are namely, blanking, piercing, notching, bending, coining, drawing, deep drawing etc. The blanking and piercing is a metal shearing operation in which a part of sheet metal is cut.

In blanking, the part of work piece that is removed from the sheet is the desired product while the remaining part is scrap. In piercing, the cut out portion is scrap which gets disposed off while the remaining part is the desired product. A die is a manufacturing tool used to manufacture components of high accuracy and in large numbers.

This paper deals with the design of blanking die used for the manufacturing of stiffening rib. This research paper focuses on designing of various components of blanking tool, two dimensional and three dimensional modelling of components. The modelling of the components was carried out on CATIA V5. The design and selection of blanking die components is carried out by following standard die design approach.

A closed die set is used for the manufacturing of stiffening rib. The guiding arrangement of plain bushing type is used for this blanking tool. The blanking tool design is governed by the material of component, thickness of component and shape and size of component. The aim is to design a blanking tool to improve the qualities of blank such as accuracy and surface of the cut.

KEYWORDS: Blanking die, CATIA, Die design, Punch Design, Rib etc...

I. INTRODUCTION

Sheet metal operations are widely used in the manufacturing of components of complex shape and size in the automobile and aircraft industry. Sheet metal operations are mainly of two types, metal shearing and forming operations.

Sheet metal forming operations like bending, drawing, deep drawing etc. are used in the manufacturing of various components and undergo a series of operations in order to obtain the desired product. Blanking and piercing are sheet metal shearing operations in which a part of sheet of predetermined shape and size is cut from the sheet metal. In blanking, the part of work piece that is removed from the sheet is the desired product while the remaining part is scrap. In piercing, the cut out portion is scrap which gets disposed off while the remaining part is the desired product.

Blanking operation consists of a sheet metal that is placed between the punch and die opening. As the punch approaches the die and comes in contact with the sheet metal, pressure is applied on the metal which results in the development of tensile and compressive forces in sheet metal. This results in the formation of crack near the edge of die opening and then crack propagates through the sheet metal and the part of sheet is sheared.

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II. OBJECTIVES OF THE STUDY

The general objective of the research is to design a blanking tool used for the manufacturing of stiffening rib by following standard die design approach and analysis methods.

The factors affecting the design of blanking tool are as follows-

- Material of sheet metal component
- Stock thickness
- Blank size
- Complexity of shape of blank

III. COMPONENT DETAILS

The dimensions of the component are shown in Figure 1.
The component details are as follows:

Name of the component: Stiffening Rib
Material of component: Mild steel
Stock thickness: 3 mm
Shear strength: 345 MPa
Tensile strength: 160 MPa

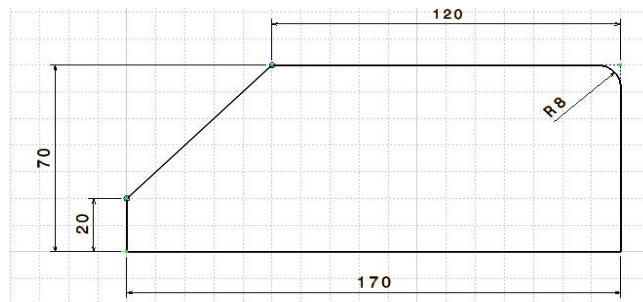


Figure 1

IV. DESIGN OF COMPONENTS OF BLANKING DIE SET

The steps in the designing of blanking die set are as follows-

- Calculate clearance of punch
- Tonnage requirement of blank
- Calculate dimensions of die block
- Calculate thickness of lower and upper bolster plates
- Calculate dimensions of stripper
- Calculate dimensions of punch holder
- Selection of Bush
- Selection of Guide Bush

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- Calculate dimensions of punch
- Selection of Guide Pillar
- Selection of Dowels and Screws

A. CLEARANCE DETERMINATION

The clearance in punch and die is the most crucial factor in the design of sheet metal component. In blanking, clearance is provided on punch while in piercing, clearance is provided on die.

The cutting clearance per side is calculated by the formula-

$$C = 0.0032t\sqrt{f_s}$$

Where,

C = Clearance per side

t = Stock thickness

f_s = Shear strength of material in MPa

$$\begin{aligned} C &= 0.0032 \times 3 \times \sqrt{345} \\ &= 0.178 \text{ mm} = 0.18 \text{ mm per side} \end{aligned}$$

Angular clearance of 2° is provided on die plate so that the blank easily withdraws through the die plate.

B. PRESS TONNAGE REQUIREMENT

The capacity of press machine necessary to provide force required in the blanking process is to be determined. The press machine must provide 30 % more force for holding the blank during operation.

Press tonnage = $1.3 \times$ Blanking force

Blanking force = $P \times t \times f_s$

Where,

P = Perimeter of blank

t = Stock thickness

f_s = Shear strength of material

$$\begin{aligned} \text{Blanking force} &= 448 \times 3 \times 345 \\ &= 463,680 \text{ N} = 47.28 \text{ Ton} \end{aligned}$$

$$\begin{aligned} \text{Press Tonnage} &= 1.3 \times 47.28 = 61.46 \text{ Ton} \\ &= 602,646 \text{ N} \end{aligned}$$

Considering Factor of Safety = 1.2,

Tonnage requirement = $1.2 \times 61.46 = 73.75 \text{ Ton}$

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The total tonnage requirement is less than the capacity of available press machine of 100 Ton. Table 1 shows the specification of the available hydraulic press

Capacity	100 Ton hydraulic press
Bed Area	800 × 600 mm
Stroke	100 mm
Shut height	500 mm

Table1

C. DIE BLOCK DESIGN

The factors affecting die block design are as follows –

- Blank size
- Stock thickness
- Die material
- Contour of blank

The thickness is calculated by the formula-

$$t_D = \sqrt{\frac{3V}{f_t} \left[\frac{\left(\frac{B}{A}\right)^2}{1 + \left(\frac{B}{A}\right)^2} \right]}$$

Where,

t_D = Die thickness

V = Blanking force

f_t = Permissible tensile stress in MPa

B = Width of slot = 70 mm

A = Length of slot = 170 mm

$$t_D = \sqrt{\frac{3 \times 463680}{160} \left[\frac{\left(\frac{70}{170}\right)^2}{1 + \left(\frac{70}{170}\right)^2} \right]}$$

$$t_D = 35.5 \text{ mm}$$

Taking into account the grinding allowance of 10 mm,

Die thickness = 35.5 + 10 = 45.5 mm

Die thickness = 46 mm

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$$\begin{aligned}\text{Margin (M)} &= (1 \text{ to } 2) \times t_D \\ &= 60 \text{ mm}\end{aligned}$$

$$\begin{aligned}\text{Length of die (L}_D\text{)} &= A + 2M \\ &= 170 + (2 \times 60) \\ &= 290 \text{ mm}\end{aligned}$$

$$\begin{aligned}\text{Width of die (W}_D\text{)} &= B + 2M + \text{allowance for locator} \\ &= 70 + (2 \times 60) + 10 \\ &= 200 \text{ mm}\end{aligned}$$

D. DIMENSIONS OF POCKET

The pocket is a member of die assembly which supports the die. During the blanking process, a large force is exerted on the die which tries to laterally expand the die. The die is enclosed in a pocket which avoids the expansion of die

Considering a margin (M) = 30 mm.

$$\begin{aligned}\text{Length of pocket (L}_P\text{)} &= L_D + 2M \\ &= 290 + (2 \times 30) \\ &= 350 \text{ mm}\end{aligned}$$

$$\begin{aligned}\text{Width of pocket (W}_P\text{)} &= W_D + 2M \\ &= 200 + (2 \times 30) \\ &= 260 \text{ mm}\end{aligned}$$

$$\begin{aligned}\text{Pocket thickness (T}_P\text{)} &= 0.8 \times T_D \\ &= 0.8 \times 35.5 \\ &= 28.4 \text{ mm} = 30 \text{ mm}\end{aligned}$$

E. DESIGN OF LOWER AND UPPER BOLSTER PLATES

The lower bolster plate supports the entire die assembly while the upper bolster plate supports the entire punch assembly.

Consider the distance between parallels of press as 30 mm.

The permissible deflection of bolster plates is assumed to be 0.001 mm.

The upper and lower bolster plates can be treated as simply supported beam subjected to concentrated force at the centre.

The thickness of bolster plates can be calculated by the formula-

$$d = \frac{Pl^3}{48EI}$$

Where,

d = Permissible deflection of bolster plate = 0.001 mm

l = Distance between parallels = 30 mm

E = Modulus of Elasticity = 2.1×10^5 N / mm²

I = Moment of Inertia

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Assuming width of bolster plate (b) to be 480 mm

$$I = \frac{bt^3}{12}$$

$$I = \frac{480 \times t^3}{12} = 40t^3$$

$$d = \frac{Pl^3}{48E \times 40t^3}$$

$$t = \sqrt[3]{\frac{Pl^3}{48E \times 40d}}$$

$$t = \sqrt[3]{\frac{602646 \times 30^3}{48 \times 2.1 \times 10^5 \times 40 \times 0.001}}$$

$$t = 34.3 \text{ mm} = 35 \text{ mm}$$

The thickness of bolster plates is taken as 35 mm.

The lower and upper bolster plates are attached to the bed and slide of press machine via clamps. Thus extra space is to be provided on the bolster plates to facilitate the easy clamping.

Considering a margin (M) = 60 mm

$$\begin{aligned} \text{Length of bolster plates (L}_{BP}) &= L_P + 2M \\ &= 350 + (2 \times 60) \\ &= 470 \text{ mm} \end{aligned}$$

$$\begin{aligned} \text{Width of bolster plates (W}_{BP}) &= W_P + 2M \\ &= 260 + (2 \times 60) \\ &= 380 \text{ mm} \end{aligned}$$

F. STRIPPER PLATE THICKNESS

The thickness of the stripper plate is calculated by the following formula-

$$t_{st} = \frac{1}{30} W_s + 2t$$

Where,

W_s = Width of stock = 175 mm

t = Thickness of stock

t_{st} = Thickness of stripper plate

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$$t_{st} = \frac{1}{30} 175 + (2 \times 3)$$

$$t_{st} = 11.83 \text{ mm}$$

The thickness of stripper plate is taken as 15 mm.

The length and width of stripper plate are same as that of die block.

Length of stripper plate (L_{SP}) = 290 mm

Width of stripper plate (W_{SP}) = 200 mm

G. DESIGN OF PUNCH HOLDER

The design of punch holder is similar to that of die block.

The punch holder supports the punch and avoids the penetration of punch into the upper bolster plate.

The thickness of punch holder is assumed to be same as that of die block.

Punch Holder Thickness (t_{PH}) = 35 mm

Margin (M) = (1 to 2) \times t_D
= 60 mm

Length of punch holder (L_{PH}) = A + 2M
= 170 + (2 \times 60)
= 290 mm

Width of punch holder (W_{PH}) = B + 2M + 10
= 70 + (2 \times 60) + 10
= 200 mm

H. SELECTION OF BUSH

A cylindrical bush is placed between the punch holder and stripper plate. During the blanking, it is necessary to hold the blank in its position. This force is provided by the bush. Also it takes up a part of impact force exerted during shearing.

A standard rubber bush of length 55 mm and internal diameter of 15 mm and external diameter of 35 mm is selected.

Number of Bushes used = 4

I. SELECTION OF GUIDE BUSH

For this particular blanking die, a plain bushing is selected. In plane bushing, the guide bush is fitted into the upper bolster plate and the guide pillar is attached to the lower bolster plate.

A guide bush is a hollow cylindrical member which guides the pillar. The clearance between the guide bush and guide pillar plays a very important role in the performance of die.

It maintains the alignment of entire tool assembly. All the components placed on die set are aligned according to the guide pillar and guide bush.

The guide bush is press fitted into the upper bolster plate. A wide range of standard bush is available in the market.

We select a guide bush which is shown in Figure 2. The part of guide bush having length of 35 mm is press fitted in the upper bolster plate.

Number of Guide Bushes used = 2

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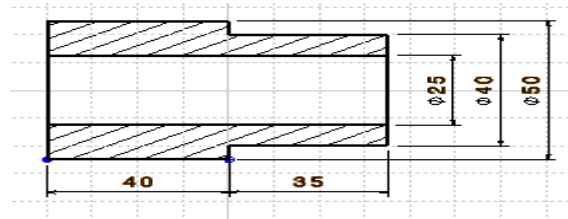


Figure 2

J. DIMENSIONS OF PUNCH

The important dimensions of the punch that are to be determined are punch length and contour of punch. We have already calculated the clearance of 0.18 mm per side. A profile of punch is obtained by subtracting the clearance from profile of die.

Punch length is a very crucial parameter. Punch is held in the punch holder, thus a certain length of punch is supported by the thickness of punch holder while the remaining length is unsupported. The punch can be treated as cantilever beam subjected to load at the free end. The punch is thus prone to buckling. The punch length should be selected by keeping in mind the further need of grinding the punch as the punch wears. Considering all the factors, Punch Length is calculated as 108 mm.

K. SELECTION OF GUIDE PILLAR

The guide pillar is attached to the lower bolster plate by press fit. All the components on die set are aligned according to the guide pillar. The punch assembly exerts a force on the guide pillar. Thus a certain length of guide pillar must be supported by the guide bush. The length of 50-80 mm of guide pillar must be supported by the guide bush and upper bolster plate. While estimating length of pillar, one must consider that after grinding of die and punch during maintenance, shut height of tool reduces and higher length of pillar is supported, thereby causing wear of pillar. The guide pillar must not come out of the upper bolster plate as it will collide with the upper slide of press and get damaged.

Considering all the factors, length of guide pillar is calculated as 166 mm.

Thus we select a standard pillar of diameter 25 mm and length 200 mm.

The top end of pillar is chamfered to facilitate easy entry of pillar into the guide bush. Also, groove of 1.5 mm depth are provided at 3 positions to overcome the fear of vacuum.

L. SELECTION OF DOWELS AND SCREWS

It is important to maintain the alignment of the components of the die set to obtain high accuracy in the manufacturing of parts. Dowel pins are used to secure the position of components of die set with respect to each other. It helps them to maintain the position and takes up the forces exerted during operation. Dowel pins are designed for shear. A large variety of standard dowel pins are available in market. We select dowel pins of diameter 10 mm. Hexagonal head screws of size M 10× 1.5 of different lengths are selected.

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M. MATERIAL AND SIZE OF DIE SET COMPONENTS

The Table 2 shows the Material and Size of Die set components.

Die Set Components	Material	Size
Upper Bolster Plate	M.S	470 × 380 × 35 mm
Die Block	D2	290 × 200 × 46 mm
Pocket	M.S	350 × 260 × 30 mm
Stripper	D2	290 × 200 × 15 mm
Punch	D2	108 mm (L)
Punch Back Plate	M.S	290 × 200 × 8 mm
Punch Holder	M.S	290 × 200 × 35 mm

Table 2

V. FIGURES OF COMPONENTS OF DIE

Figure 3, 4, 5 and 6 shows the various components of Die Set and Figure 7 and 8 shows the assembly of Die Set. Figure 3 shows the 3D Model of Die Block, Figure 4 shows the 3D Model of Pocket, Figure 5 shows the 3D Model of Lower Bolster plate, Figure 6 shows the 3D Model of Guide Pillar and Figure 7 shows the Exploded View of Die Set and Figure 8 shows the Assembled View of Die Set

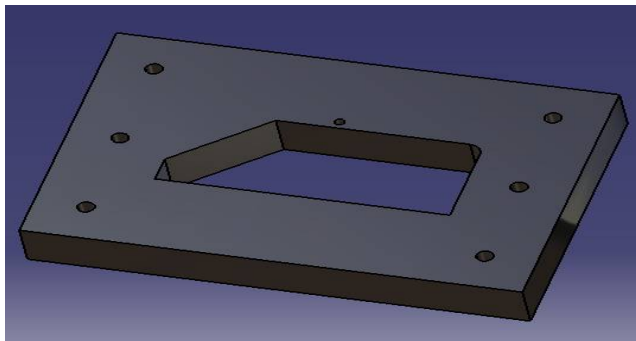


Figure 3

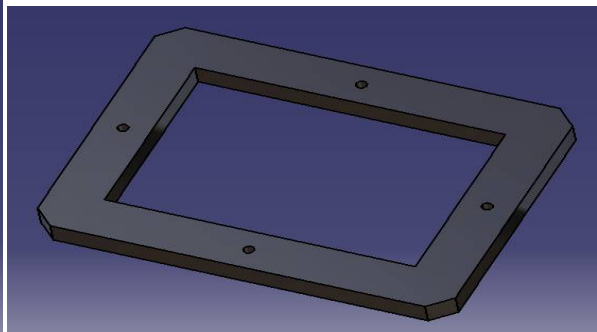


Figure 4

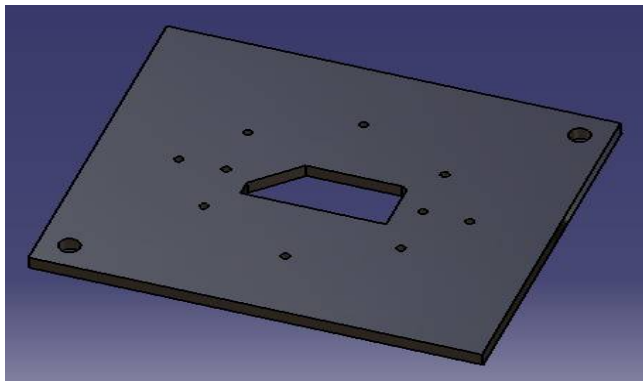


Figure 5

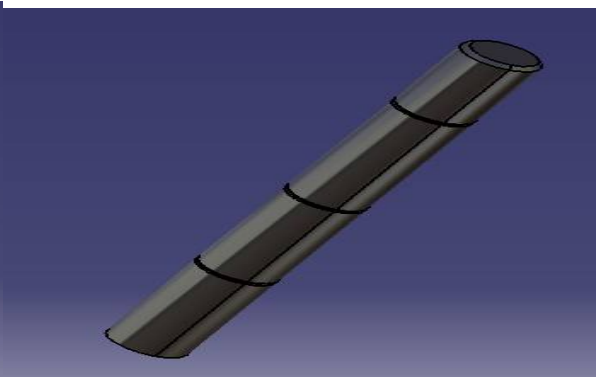


Figure 6

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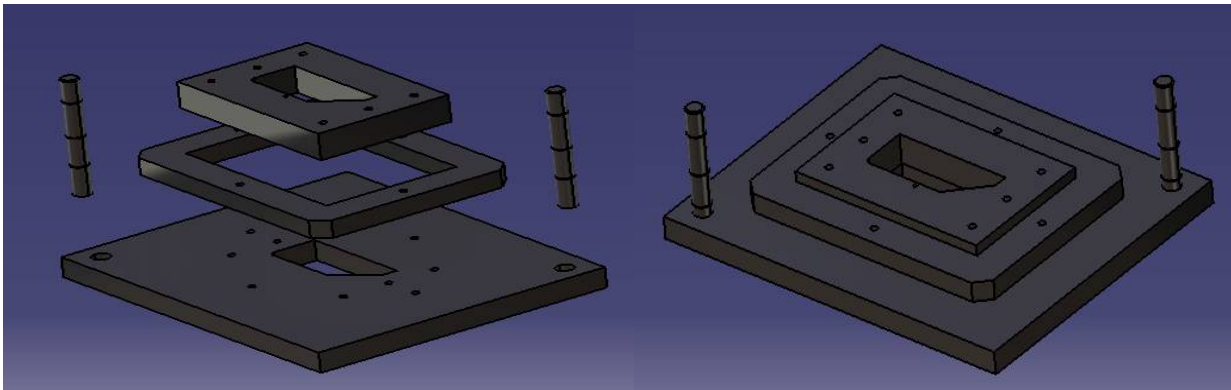


Figure 7

Figure 8

Figure 9, 10, 11,12,13,14, 15 and 16 shows the various components of Punch Set and Figure 17 and 18 shows the assembly of Punch Set. Figure 9 shows Contour of Punch, Figure 10 shows 3D Model of Punch, Figure 11 shows 3D Model of Punch Holder, Figure 12 shows 3D Model of Stripper, Figure 13 shows 3D Model of Punch Back Plate, Figure 14 shows 3D Model of Upper Bolster Plate, Figure 15 shows 3D Model of Bush, Figure 16 shows 3D Model of Guide Bush, Figure 17 shows the Exploded View of Punch Set and Figure 18 shows the Assembled View of Punch Set.

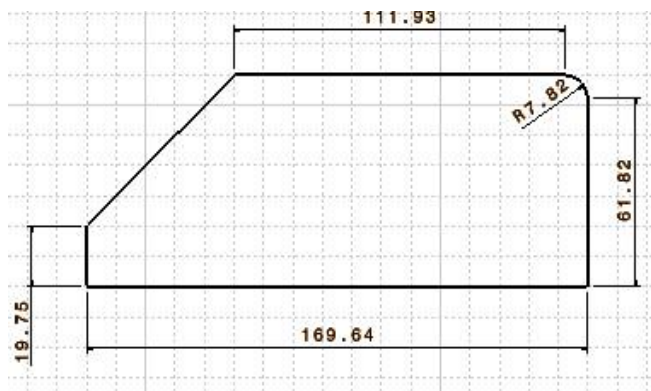


Figure 9

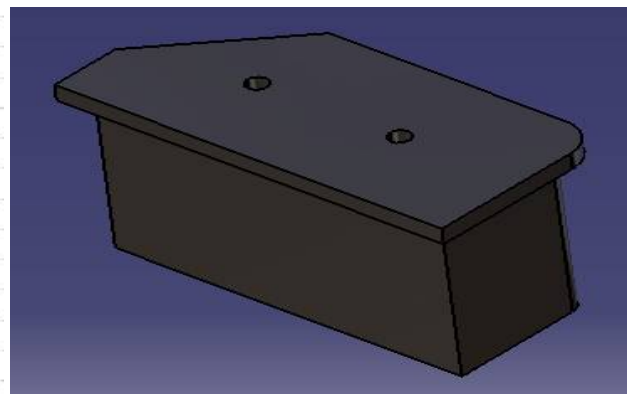


Figure 10

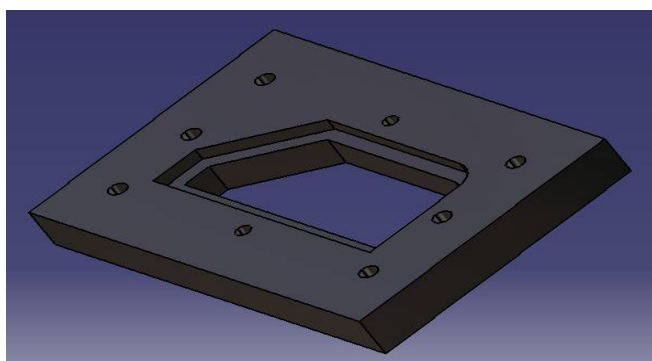


Figure 11

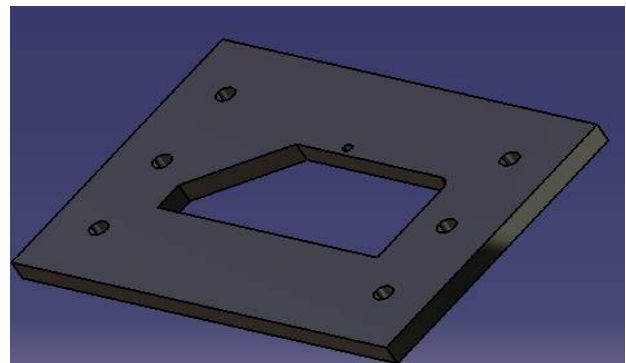


Figure 12

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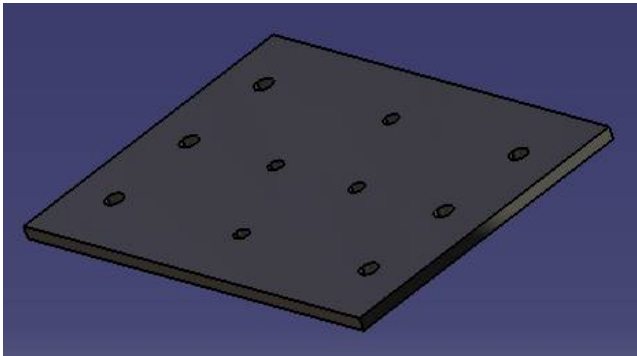


Figure13

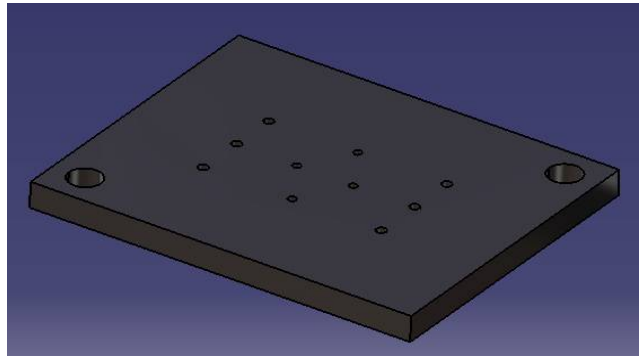


Figure 14

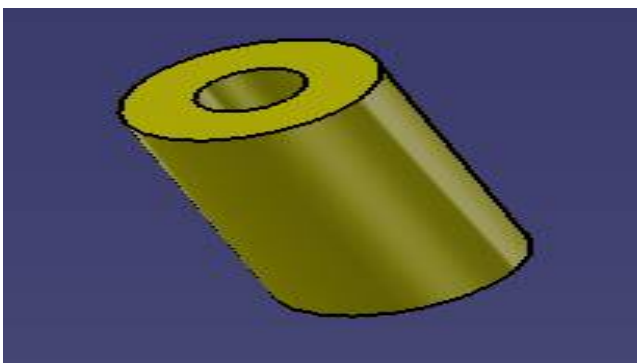


Figure 15

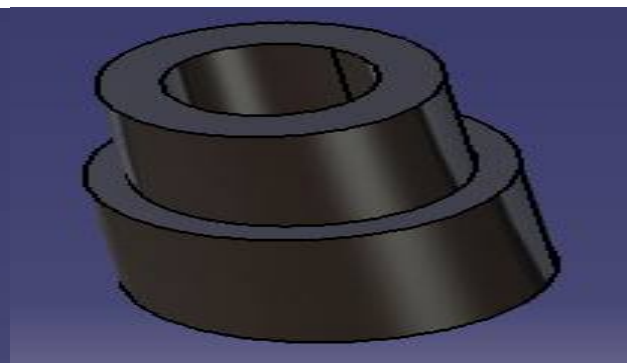


Figure 16

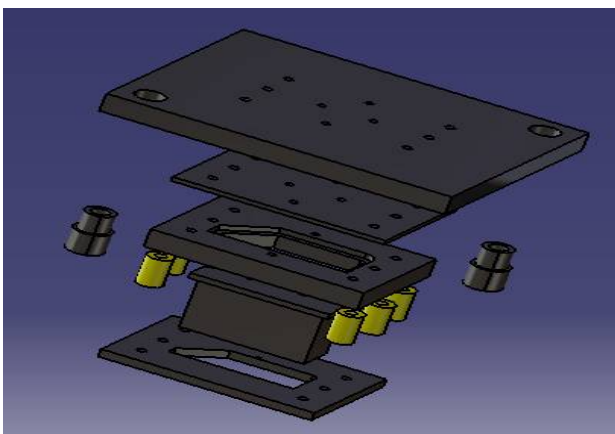


Figure 17

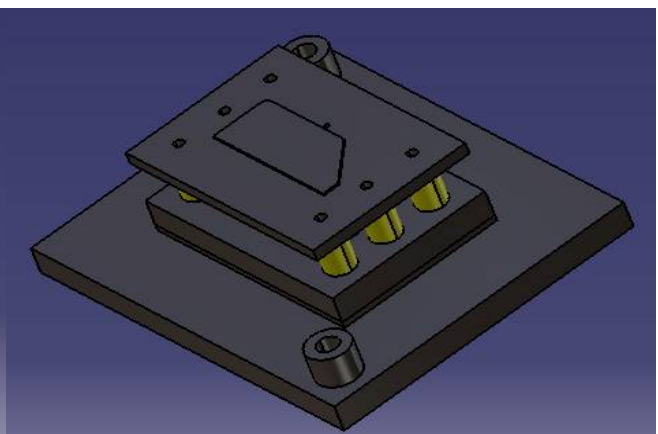


Figure 18

Figure 19 shows the 3D Model of Blanking Die Tool which is the union of Die Set and Punch Set.

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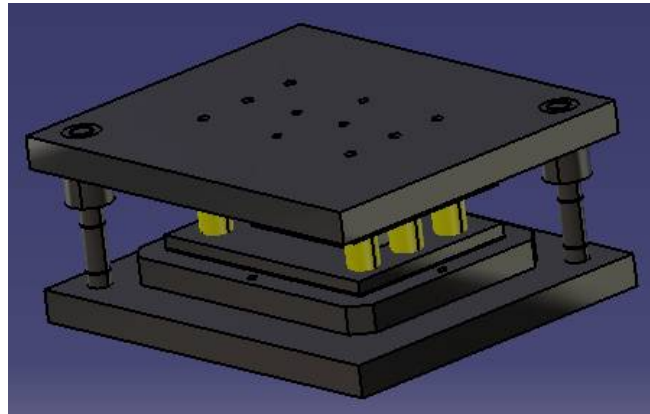


Figure 19

VI. CONCLUSION

The design of Blanking tool for stiffening rib is successfully done by using the standard design approach and also applying the practical knowledge. The various parameters of the components of die tool were calculated and were modelled in Catia V5 software. The tonnage requirement of blanking tool was less than the available hydraulic press in the factory. The 2D and 3D drawings of each component will help in the manufacturing and assembly of the components.

Thus designed blanking tool will result in high accuracy, good surface finish of blank and smooth and efficient working of tool.

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